Neutron Star Astrophysics at the Crossroads: Magnetars and the Multimessenger Revolution
Proceedings IAU Symposium No. 363, 2023
E. Troja & M. G. Baring, eds.
doi:10.1017/S1743921322000849

Exploring Populations of Low Mass Merging Compact Binary Systems with Single Einstein Telescope

Neha Singh and Tomasz Bulik

Astronomical Observatory, University of Warsaw, Al. Ujazdowskie 4, 00-478 Warsaw, Poland
email: nsingh@astrouw.edu.pl

Abstract. Einstein Telescope (ET), a the future third generation gravitational wave detector will be sensitive to gravitational wave signal down to 1 Hz. We present an algorithm to estimate the parameters of the low mass merging compact binary systems such as localisation, chirp mass, redshift, mass ratios and total mass of the source which are crucial in order to estimate the capability of ET to study various compact binary populations. We analysed the compact binary populations of (i) Pop I and Pop II, (ii) Pop III, and (iii) globular clusters, with single ET.

Keywords. gravitational waves, stars: neutron, black hole, methods: data analysis

1. Introduction

Due to an improved low-frequency detection sensitivity ET will observe low mass binaries for a longer period of time in the detection band before their merger. With the lowest frequency detection sensitivity for ET-D being down to 1Hz, the BNS signals can stay in the detectable band from a few minutes to several days. In this work we explore the capability of ET as a single instrument to study longer duration signals from coalescing low mass compact binary systems and present a simplified approach to estimate the parameters of low mass merging compact binary systems. Given the high detection rate of merging compact binaries with ET, it will be a useful instrument to conduct population studies. We analyse realistic populations of compact binary systems originating from Pop I and Pop II, Pop III, and globular cluster populations in this work.

2. Method

The methodology of the analysis in this work is as follows: We construct a *mock population* of compact binary systems from three sets of populations: (i) field binaries originating from population I and population II stars (Pop I+II), (ii) binaries evolving in globular clusters (GC) and (iii) binaries from population III stars (Pop III). We assume that the ET detector is located at the Virgo site and has the ET-D design sensitivity. For every compact binary system, from each of the three sets of mock population, the gravitational wave signal in the ET detection band is analysed by taking into account the change in the antenna pattern with the rotation of the Earth. The binary source is considered as *detected*, if it crosses a detection threshold set on the SNR. The posterior distribution for chirp mass and redshift for each detected source is estimated using the algorithm described in Singh & Bulik (2021). The algorithm was first tested for a population of binary neutron stars distributed uniformly in co-moving volume. The results for these binary neutron stars are shown in Figure 1. We then analysed the parameters: chirp mass $\mathcal{M}$, redshift z, and the merger rate of the inspiraling compact binary systems

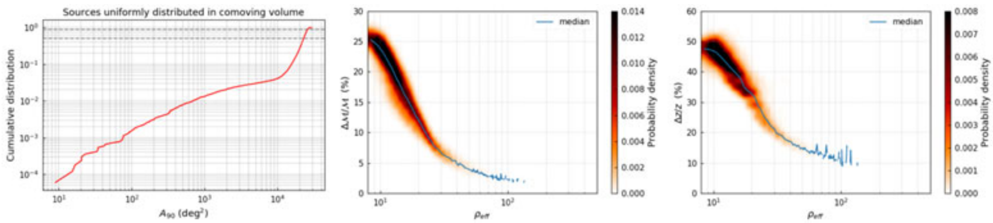

Figure 1. Parameter constraints: The constraints on localization, chirp mass $\mathcal{M}$ and redshift z Singh & Bulik (2021)

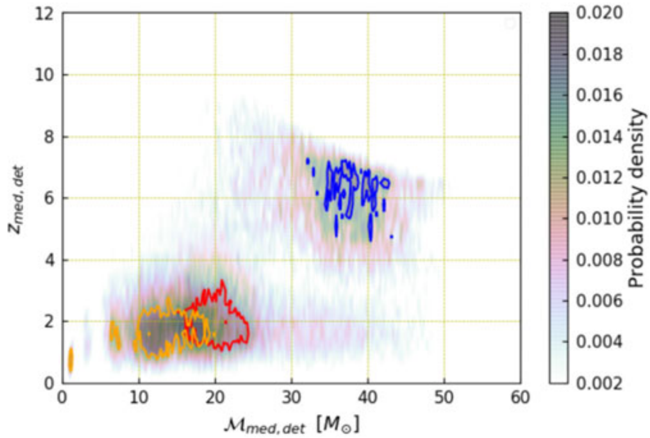

Figure 2. Distinguishablity with single ET: The orange, blue and red contours enclose the 90% region the recovered values of Pop I+II, Pop III, and the GC population respectively Singh et al. (2021).

of Pop I+II, Pop III, and GC population. In order to see the distinguishability of each population we plot all of them in Figure 2. The normalization of each of the three sets : Pop I+II, Pop III, and GC depends on the merger rates of each of these populations. As seen in Figure 2, the three regions are clearly distinguishable.

3. Conclusions

We conclude that the ET as a single instrument can break the chirp mass - redshift degeneracy. The three sets of populations (i) Pop I+II, (ii) Pop III, and (iii) GC, represent different metallicities and hence different age of the binary population and represent different formation scenarios. Thus the analysis presents the capability of single ET to detect and distinguish different compact binary populations. We show if the populations of compact binaries are separated in $\mathcal{M} - z$ space, then ET as a single instrument is capable of detecting and distinguishing these different compact binary populations. If the populations overlap in $\mathcal{M} - z$, then it will be necessary to consider other parameters such as spin to estimate the distingushibility.

Acknowledgement

We acknowledge the support from the Foundation for Polish Science grant TEAM/2016-3/19 and NCN grant UMO-2017/26/M/ST9/00978.

References

Singh, N. & Bulik, T. 2021, arXiv:2107.11198
Singh, N., Bulik, T., Belczynski, K., et al. 2021, arXiv:2112.04058

https://doi.org/10.1017/S1743921322000849 Published online by Cambridge University Press